The Final Frontier or Lost in Space?: System Analysis and Decision Support For A Multi-Agency, Multi-Disciplinary Project

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Abstract

The Upper Rio Grande Basin Water Operations Review and Environmental Impact Statement (EIS) is a multi-agency effort that is using a Geographic Information System (GIS) base to evaluate operational changes to improve river system management. The Upper Rio Grande Water Operations Model (URGWOM-Planning version) represents the backdrop of an institutionally and physically complex river system. There are three joint-lead agencies, five cooperating agencies, and other participants involved in this formal EIS planning process. With a host of different scientific disciplines on ten technical teams, GIS was the choice of the Interdisciplinary Team to "somehow put it all together and make sense of it", a Rosetta stone for the Tower of Babel. This paper documents the trials, tribulations and most importantly, techniques for successfully using GIS for individual resource analysis and integrating these into a basis for making management decisions.

Introduction

The study area and basin resources discussed in this summary of lessons learned are part of the upper Rio Grande basin (Figure 1) from the Closed Basin in southwestern Colorado to Fort Quitman, Texas. The Upper Rio Grande Basin is complex both physically and institutionally. It includes an extremely variable water supply, trans-basin and native basin water, rising population, competing water needs, endangered species, interstate compact between 3 states, international treaty with Mexico, 19 Pueblos whose water rights have not been defined, and current litigation ongoing in the basin.

Working within this framework, the Upper Rio Grande Basin Water Operations Review and Environmental Impact Statement (EIS) http://www.spa.usace.army.mil/urgwops/ is in its fourth year of a five-year formal EIS process (NMISC 2000) and will result in an integrated water operations plan for the Upper Rio Grande Basin. A planning version of the Upper Rio Grande Water Operations Model (URGWOM) http://www.spa.usace.army.mil/urgwom (USACE 1997) represents the historic and hydrologic constraints of the basin. There are about 70 technical specialists that are working together in ten technical teams that represent three lead agencies, five formal cooperating agencies and other participants, and about 20 different scientific disciplines. The teams are to determine impacts of specific actions on the human, aquatic, riparian, and other resources of the basin.

In view of the scale and complexity of the EIS, Geographic Information System (GIS) was identified as a compass for managing basin data through its lifecycle of: 1) Collection, 2) Organization/Compilation, 3) Evaluation, 4) Analysis, and 5) Synthesis. Throughout all of these steps, data sharing is essential, both within the teams, and ultimately to the affected public and others that must build on this information for the future.

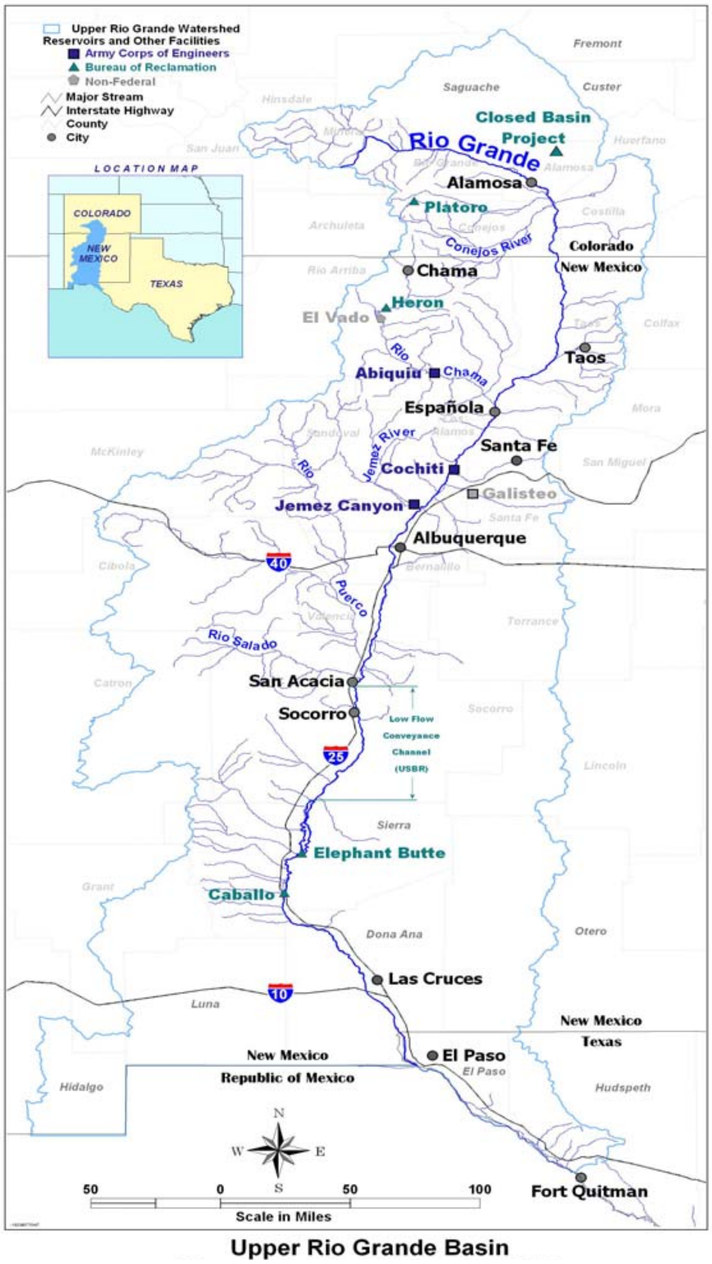

Figure 1: Location Map of Upper Rio Grande Basin

Geospatial Issues: Problems and Solutions

Spatial analysis, and the organization of information relevant to an EIS covering portions of three western states, has been a significant challenge. The scale, complexity, and length of this project have presented major interpretive and analytical issues not only for those familiar with the EIS process, but also for a variety of technical staff used to analysis on a much more localized geographic scale. For members of the team responsible for GIS analyses, the expansive scale of the EIS has – to paraphrase the words of a former New Mexico governor – "opened a box of Pandoras". Having opened that box in the early stages of this project, we would like to share with you how we have addressed and resolved some of the major issues relating to spatial analysis for a project covering this large area.

The following discussion is arranged thematically and covers a number of issues that have been central to GIS analysis in our project, and hopefully will be of interest to others in the design and development of their projects – large or small.

Data Quality

Analyzing spatial phenomenon at any macro-scale inevitably raises the issue of data quality. Variations with respect to variables such as methods of data collection, survey coverage and intensity, and data currency (i.e., the age of a particular dataset) are critical in evaluating whether data will, or will not be suitable in a given context. The accuracy and precision of datasets are also key features that condition how useful information may be for a specific type of analysis.

Given the large geographic frame and long-term chronological perspective adopted by the EIS, variations in data quality have been abundant. (The study area covers 78,000 square kilometers (30,000 sq. miles), a linear distance of 1100 kilometers (700 miles), a period of data collection spanning more than a century, and periods of human occupation extending over 14,000 years.) These differences are manifest from one region to another and through time, as well as being visible in similar types of data collected at similar times.

Our approach to these variations was to understand them in qualitative and quantitative terms, as well as geographically. Just as older USGS topographic maps depicted (by way of a small inset map) where there were areas surveyed at different times, we emphasized to all of our team members that a graphical and spatial summary of data quality – including details concerning data collection methods, dates and resolution - would be required of everyone. What we wanted to understand, and later convey to others, is where our best quality information was located and where our most significant data gaps existed. Maps were then generated for a variety of resource types: archaeological, riparian, aquatic, water operations, land use, geomorphic, water quality, demographic and hydrologic.

When combined, these maps provide a clear indication of where we have quality, detailed evidence of significant time-depth and where such information is lacking. As a tool for planning the future development of our project, these maps are critical – particularly in determining which areas can sustain different types of analyses. For some resources, analysis in areas with detailed data aided the team in determining how to approach similar areas with less data. In the final, presentational phase of the project, these maps will also serve as a very important device for communicating project design decisions and results to the general public – e.g., why certain types of work were conducted in some geographic areas, but not others.

Figure 2 (below) illustrates the value of evaluating data quality issues using GIS. The example we present here involves understanding the distribution of cultural resources – historic and prehistoric sites along the Rio Grande and one of its major tributaries, the Rio Chama. The sites displayed in this graphic represent several thousand cultural resources, spanning a period of occupation from ~12,000 B.C. to the recent historic period. These sites have been recorded over a period of more than a century - some having been surveyed multiple times and others only once. Variations with regard to the type of detail recorded for these sites, the quality, and their accuracy, therefore vary widely.

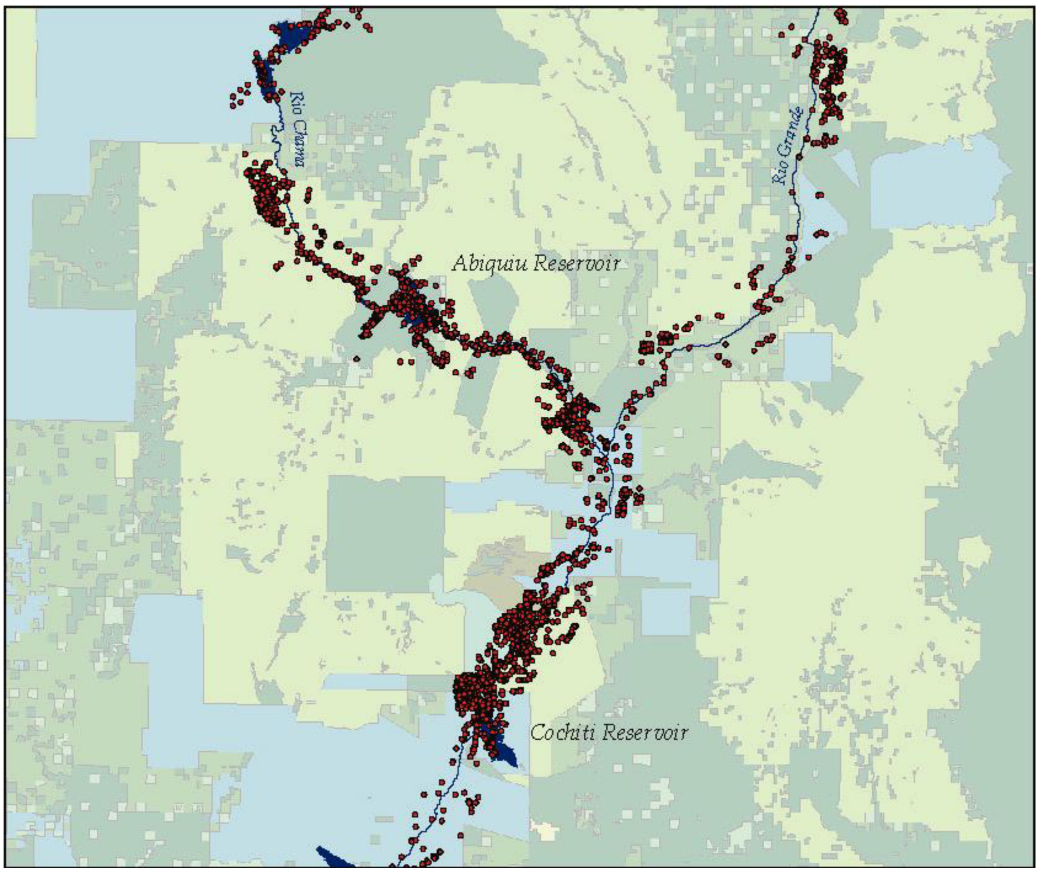

Figure 2 Evaluation of Archaeological Site Distribution and Data Quality Along the Rio Grande and Rio Chama (Northern New Mexico)

Some of the major differences in the density of known archaeological and historic sites in the Rio Grande basin are clearly due to variations in the intensity of field investigations, and in land management/ownership. In this map of the Rio Chama and upper Rio Grande, high densities of archaeological sites are interrupted by a number of areas where sites are more sporadically distributed. Large, aggregated clusters of sites around reservoirs such as Abiquiu (in the north) and Cochiti (to the south), can be explained in part by the fact that these parcels are federal (public) lands where there is a legal requirement to survey and inventory cultural resources. Other thematic data collected for the project such as riparian vegetation, geomorphology and hydrology, obviously need to be evaluated in a similar way – with an understanding of the reasons for variations in quality through time and space.

Data Scale and Resolution

Since the scope of our project and its data collection efforts were both *broad* and *deep*, there were a number of interesting challenges in trying to meld data collected from very detailed, localized analyses (e.g., water quality data) on the one hand, with broad, basin-wide evaluations on the other. GIS technology, while presenting an array of powerful analytical tools, is not sufficiently thoughtful to prompt users before they do inappropriate or unfortunate things – in particular, mixing data from disparate sources, scales, map projections, datums, etc. with one another.

The power of GISs to create derived datasets (i.e., data resulting from the combination of multiple information sets – such as erosion potential maps from soils and topographic data layers) is both a boon and a bane. Keeping track of what multiple data overlays mean and what the confidence interval is at each step in this iterative process is related more to 'grayware' (human intelligence) than to software. Complex, multivariate, multi-resource analyses make it fairly easy to lose sight of what our data 'is' at these different stages, and whether it is sufficiently accurate, precise and detailed to provide reliable conclusions given what we are asking of it.

Metadata (or data about data) provides some insight into the appropriateness of using particular sets of information in a given context. Nevertheless, we soon depart from the security of metadata once we begin to combine layer with layer, conflate several years of data into one, combine map projections, and attempt to assess impacts for multiple resource types. At this point we are 'off the map' and in an interpretive landscape that must be navigated by professional judgment, rather than fixed rules and protocols.

Our EIS has thus far involved numerous examples of data suitable for one scale, and purpose, but not for others. The availability of USGS digital data for the project area as a whole, such as 1:100,000 drainages for example, was an obvious convenience for broad-brush characterizations and calculations. The suitability of this data for more detailed analyses of impacts to cultural resources and endangered species was more debatable, however, and ultimately required digitizing about 100,000 points to create a 1:24,000 coverage of the upper Rio Grande basin.

Similar decisions about whether to use existing data, or commission new data gathering efforts, surrounded our analysis of aquatic habitat in reservoirs along the Rio Grande. Difficult decisions about money, data currency, quality, and cost/benefits were raised in trying to determine whether 30 year old topographic data (pre-inundation maps) and the lack of current data regarding sedimentation were adequate or whether the cost (and time) associated with commissioning new LIDAR or photogrammetric data were feasible given our project funds and schedule.

Tradeoffs of this type are common with GIS and complex EIS analyses. Provided that we are aware of, and disclose, the interpretive limits of our data, and can be creative about getting the most from what we have, the risks of doing something untoward will be minimized.

Data Standards

Standardizing GIS data is a laudable goal that seems achievable and sensible in some contexts, and less so in others. Since our study area covers segments of three states, for example, selecting a set of map parameters that suits individuals working only in New Mexico, at the expense of other teams working across the Upper Rio Grande as a whole, would not have been practical. Nevertheless, we did try to provide guidance to our team members regarding preferred map projections, datums and units, to be followed wherever and whenever possible.

Since reprojecting information from one set of map parameters (such as Latitude/Longitude) to another (like State Plane coordinates) can involve significant errors if repeated multiple times, we tried to keep as much of our data in its original form as possible, and convert/reproject this data only when circumstances required. We have also tried to keep a record of these conversions so that details associated with a particular set of information (metadata plus), highlights both the original format of that information, *as well as* any conversions that have taken place in the course of its evolution.

Some aspects of standardization have been easier to achieve and more essential to the successful representation and understanding of our results. Using standardized map scales, cartographic conventions (such as color schemes, hatching and fonts), and map components (scale bars, north arrows, etc.), not only is aesthetically more attractive and representative of a corporate/team approach, but also creates less confusion when these data are presented to the public and other end-users.

<u>Data Accessibility and Delivery</u>

The organization of data and the arrangements to share it within the life of a project are obvious features of GIS support that need to be considered in successfully completing large EISs. As a result, part of our efforts in undertaking this project have been devoted to organizing and delivering both spatial (GIS) related data, as well as a wide variety of other documents (including graphs; ground-based, aerial and satellite imagery; reports; statistics and drawing).

Coherent archives of digital and documentary data are an investment not only in good project design and logistics, but also provide an important historical snapshot of our knowledge at a given time and place. Archives are not only for the here and now, but are a gift (to the future) that will keep on giving. Thoughtful consideration of the nature and design of such archives is therefore an effort worth making – both for immediate projects needs and for long-term, future needs that are more difficult to forecast.

Our EIS has involved multiple agencies and partners and a plethora of data in a daunting variety of formats. The objective from the beginning has been to try to integrate the rapid delivery, display and search of these archives with tools that are rather inexpensive and widely available, so as not to restrict the information we have collected (except in circumstances where security is required.) We have opted for Web-based GIS and document management delivery systems that are integrated, wherever that is possible. So, for example, documents that are included in our NEPA Administrative Record have been coded with a geographic footprint which enables highly efficient searches to be executed on the basis of geographic parameters.

Traditionally, document management systems have relied on rather idiosyncratic classification systems which often make retrieving documents from an archive either slow, ineffective or both. The results of such searches are often large amounts of irrelevant material, and a large measure of frustration. Because geographic search parameters such as drainage basins, county boundaries and USGS quad maps, are a less ambiguous search criteria than those typically used in document retrieval systems, the time required for such searches is reduced and their productivity is enhanced.

Another aspect of rapid data retrieval has been formatting our data (particularly large documentary records and image datasets) into highly compressed forms suitable for rapid retrieval, display and searching. Opting for file formats that provide optimal file compression and minimize loss of resolution has been our goal throughout the project. Highly compressed file formats such as Lizardtech's MrSID and DjVu – image and document compression formats, respectively – have been of considerable assistance to us in creating data that can easily be shared electronically, either via FTP, e-mail or the Web. Many of our paper documents have also been processed using Optical Character Recognition (OCR) software, which adds a further enhancement to our digital archive: i.e., the ability to search reports, publications, etc. via user defined search parameters, rather than by a system-defined classification. Freeform, hypertext searches of large documents, many of which never had an index associated with them, is a huge advantage in rapidly locating information.

When tools of this kind are combined with the capability of searching for data using spatial analytical tools, like GIS, the result is greater than the sum of its parts. The fusion of geography and traditional archiving protocols has made the organization and retrieval of large amounts of our documentary and geospatial data far easier and much more efficient.

Problem Solving Approaches

Since GIS analyses were recognized at the onset of this EIS as having a major role to play in the design and development of our study, it was extremely important to communicate some of the fundamental principles of spatial analysis to our team members and partners. Given their variegated expertise and experience with GIS, it was essential to design different vehicles for communicating this information to them and to continue this dialog on an ongoing basis. These different communication devices included:

- '**Cartoons**' – *i.e., a schematic, graphic depiction of what a particular type of analysis would look like, drawn in a sequence of steps and detailing what types of data would be involved, how they would be combined in a series of steps [cartoon panels], and what the desired result should be (and look like)*
- **Pilot Projects**
- **Workshops**
- **Thematic Presentations - Internal** *(i.e., specific themes designed for short presentations)*
- **Presentations – External** (*e.g., to Acequia Associations, Tribes, etc.*)
- **GIS Liaisons** (*i.e., staff specifically assigned to each team to answer questions and attend meetings*)
- **Public Meetings**

Our experience over several years in trying to communicate with our colleagues about GIS issues highlighted the fact that different audiences may require different approaches. Likewise, it was clear to us that multiple approaches were not necessarily redundant, since different methods tend to reinforce a message to some audiences, but reach other groups for the first time. We also found that maps may be the best tool to communicate a point to one audience, or about one resource, but other vehicles were more effective with others (e.g., output from GIS in the form of statistics, histograms, tabular data, documents or imagery).

Finding the best combination of these approaches requires: (1) defining *what you want to know*; (2) understanding data quality (and the interpretive/analytical limits associated with variations within and between datasets); (3) making informed decisions about how variations in data quality will be addressed (and addressed in a way that considers the potential impact to others involved in the analysis); (4) communicating well between different technical experts/program managers concerning what has been done analytically (and with what); (5) when the results are available, deciding collectively how these will be presented, to what audience(s)?, in what form (paper, Web, digital files)? and as what (graphs, text, maps, images)?; and finally, (6) leaving enough time to determine how to arrive at the best representation of your results given your target audience and the constraints on available project resources. Finding a suitable balance between presentations appropriate for a lay/public audience, while at the same time being technically sound, defensible and compliant with appropriate laws, requires time for thoughtful consideration of these complex issues.

Conclusion

Map makers, it has been said, face their greatest challenge not in deciding what they put in, but what they leave out. Our project, like other EISs, however, may make its greatest contribution by identifying what has been left out – whether that be questions left unresolved, the recognition of data gaps, or an emphasis on issues still to be addressed. The data created in projects such as ours, as many others like it, generate an important historical baseline of information that provides the basis for future studies. Organization of coherent, well organized spatial and documentary databases are more than simple *librarianship*. Instead, they provide a critical analytical step in designing future research and in better understanding complex environmental phenomena.

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